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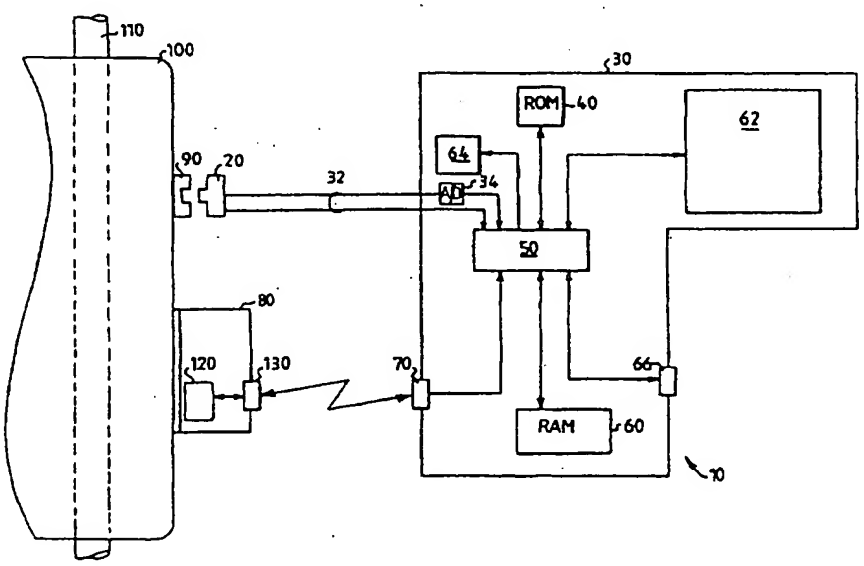

(57) Abstract

The invention relates to a method for evaluating the condition of a machine (100) with a measuring point (90), which method is performed by a movable analysis apparatus (30). The method comprises the steps of producing a condition value, by means of measuring at the measuring point, which condition value is dependent on the actual condition of the machine, and storing the condition value in a writable information carrier (120) which is placed by, or in the vicinity of, the measuring point (90) so that the condition value subsequently can be used as a reference condition value. The invention further relates to an apparatus for performing the method and a device for co-operating with the analysis apparatus and for mounting by a measuring point on the machine (100).

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Condition analyzer

Technical field

The present invention relates to a method for generating a condition value for a measuring point on a machine having a measuring point, and a system for performing the method.

State of the art

Machines with moving parts are subject to wear with the passage of time, which often causes the condition of the machine to deteriorate. Examples of such machines with movable parts are motors, pumps, generators, compressors, lathes and CNC-machines. It is known to, more or less regularly, investigate the operating condition of such machines. The operating condition can be determined by measuring the amplitude of vibrations in the bearings and by measuring temperature changes on the casing of the machine, which temperatures are dependent on the operating condition of the bearing. Such condition checks of machines with rotating or other moving parts are of great significance for safety and also for the length of the life of such machines. It is known to perform such measurements on machines completely manually. This ordinarily is done by an operator with the help of a measuring instrument performing measurements at a number of measuring points on a machine. The measuring data obtained by means of the measuring instrument for each measuring point is noted down on a pre-printed formula. For a machine it can be necessary to have a number of measuring points in order to later be able to determine the overall operating condition of the machine. For example, three measuring points are often used for the measurement of vibrations of a motor, in such a way that the vibrations are measured in three mutually perpendicular directions, i.e. in the X-direction, in the Y-direction and in the Z-direction. The operator must note down each measured

value on the formula. It is furthermore necessary for the operator to evaluate the measured values so that he can make a judgement on whether the measured amplitude measurement values indicate a change for a measuring position so that the machine can be serviced if the measured values indicate wear. This places a large demand on the professional knowledge of the service personnel of which vibration and temperature measurement values are acceptable and which measurement values are not acceptable.

In order to identify damage to bearings it is known to use a shock impulse measuring apparatus by means of which damage to bearings can be determined in machines with rotating machine parts. In order to perform such measurements at a measuring point, the diameter of the shaft and the rotational speed of the shaft are set on a measuring scale. These values, which are set by hand, function as a reference level. If the measured values measured by means of the measuring instrument are greater than the reference level, this can be indicated by means of a warning lamp or by means of a sound signal.

It is known from EP-0 194 333 to provide each measuring point with identity data which is automatically readable by means of a separate reading probe. EP-0 194 333 also describes that the characteristic data values for the measuring point are readable at the measuring point so that the above described reference value can be generated automatically. The reference value is consequently calculated in a standardized and unambiguous way from the characteristic data values. Consequently, according to this known technique, the one and the same reference value is valid for all bearings with a certain shaft diameter and a certain rotational speed.

EP-0 211 212 describes a measuring instrument for detecting and evaluating data representative of the condition of a machine. The described measuring instrument has a measuring probe which is combined with a sensor probe for reading a

measuring point code, whereby the measuring probe and the code sensing probe are provided in a common mobile casing.

Disclosure of the invention

The problem which is to be solved by means of the present invention is to provide a method which permits an increased accuracy in detecting changes of the condition of a machine.

This problem is solved according to the invention by means of a method for evaluating the condition of a machine with a measuring point, which method is performed by a movable analysis apparatus comprising the steps of:

- producing a condition value, by means of a measurement at the measuring point, which condition value is dependent on the current condition of the machine; and
- storing the condition value in a writable information carrier (120) which is placed on, or in the vicinity of, the measuring point 90 so that the condition value subsequently can be used as a reference condition value.

According to a preferred embodiment, the reference condition value is produced depending on a measured value, such as a vibration measured value measured in connection with the final inspection of a newly manufactured machine, and on relevant interpreting information, such as shaft diameters and rotational speeds for a rotatable shaft on a machine. With the object of providing a determination of whether some measurable condition change is present, a method according to the invention is performed which comprises the steps of:

a) producing a condition value, which condition value depends upon the actual condition of the machine at the measuring point; and of

b) acquiring a reference value, indicating the condition of the machine at the measuring point at an earlier time point, from an information carrier which is placed by, or in the vicinity of, the measuring point.

Description of the drawings

In order to make the present invention easy to understand and produce, it will be described with reference to the appended drawings:

Fig. 1 shows a schematic block diagram of an embodiment of a condition analyzing system according to the invention.

Fig. 2A shows an embodiment of a sensor unit which comprises an interface for communication with an information carrier at a measuring point.

Fig. 2B shows an embodiment of a device at a measuring point comprising an information carrier and an interface for communication with the interface according to Fig. 2A.

Preferred embodiments

Fig. 1 shows a schematic block diagram of an embodiment of a condition analyzing system 10 according to the invention. The condition analyzing system comprises a sensor unit 20 for producing a measured value dependent on movement and, more precisely, dependent on vibrations.

The sensor unit 20 is connected to an analysis apparatus 30 via a conductor 32. The analysis apparatus 30 comprises a non-volatile memory 40, a microprocessor 50 and a read/write memory 60. A computer program is stored in the read memory 40, and by means of this computer program the function of the analysis apparatus 30 is controlled. When it is written below that the microprocessor 50 performs a certain function, it shall be understood that the microprocessor runs a certain part of the program which is stored in the memory 40.

The microprocessor 50 is connected to a display unit 62. By means of the display unit 62 a user of the condition analyzing system is informed of the condition of the current measuring point in clear text. The production of a condition value is

described more closely below. The display arrangement can comprise, on the one hand a screen, on the other hand a printer unit, so that the user can have the condition value from the measuring point printed out if so desired.

According to a preferred embodiment the analysis apparatus 30 comprises a screen 62 on which relevant information is shown during the measuring, and a diskette station 64 in which a diskette is introduceable. In this way the user with the help of the analysis apparatus 30 collects the condition values for a plurality of measuring points and save all the information on a diskette removably introduced into the diskette unit 64. The microprocessor 50 is further connected to an information port 66, by means of which the apparatus 30 can be connected to a separate information processing unit.

The analysis apparatus 30 is equipped with an interface 70 for the exchange of data with a device 80. When the system is operative, the device 80 is firmly mounted on or at a measuring point 90 on a machine 100 with a movable part 110. A measuring point can comprise a connection coupling firmly attached to the casing of the machine to which the sensor unit is removably attachable. The connection coupling can, for example, be formed of a bayonet coupling. A measuring point can comprise a threaded recess in the casing in which the sensor unit is screwable. In the last case the sensor unit 20 comprises corresponding threads so that it can be introduced into the recess like a screw.

Alternatively, the measuring point is marked on the casing of the machine only with a painted mark.

The machine 100 exemplified in Fig. 1 has a rotating shaft 110 with a certain shaft diameter d_1. Shaft 110 in the machine 100 rotates at a certain speed of rotation V_1 when the machine is in use.

The apparatus 80 comprises an information carrier 120 which is equipped with information on the identity of the measuring point and interpreting information. The information carrier is furthermore equipped with at least one condition value K_{ref} which can be used as reference for determining a possible change in the condition.

The identity information can be formed of, for example, the identity number of the measuring point or of a data string which identifies both the machine 100 and the measuring point 90. The machine 100, which is only partly shown in Fig. 1, can comprise a number of measuring points and a number of moving parts so that the condition of different parts of the machine can be determined individually. The interpretation data stored in the measuring point device 80 can comprise a first computer word indicating the above mentioned shaft diameter d_1 and a second computer word indicating the speed of rotation V_1. The information carrier 120 is connected to an interface unit 130 for exchanging information with the interface unit 70 of the analysis apparatus 30. An operator transports the portable analysis apparatus 30 to the measuring point for which the condition value is to be determined and attaches the sensor unit 20 to the measuring point 90. According to one embodiment the sensor unit 20 is provided with a change-over switch (not shown) which closes in dependence of the sensor unit being brought into contact with the measuring point 90. When the change-over switch closes, an activating signal is produced which, via the bus 32 is delivered to the microprocessor 50 and thereby activates the microprocessor to perform an analysis routine. An actual condition value is determined by the analysis routine, and a reference value K_{ref} acquired from the information carrier 120. The reference value K_{ref} indicates the condition value for the individual machine for the same measuring point at an earlier point of time. The reference value K_{ref} is stored in the information carrier in the same way as described below.

When the machine is new from the factory or when a bearing for a rotatable shaft 110 is renovated or exchanged, a condition value K_{ref} for each measuring point 90 of the machine 100 is determined.

The condition reference value for the measuring point is determined according to a preferred embodiment by producing a measured value indicating the vibration or temperature of the machine at the measuring point and, in a known way, with the help of interpretation information, such as shaft diameter and speed of rotation of the shaft, transforming the measured value into a condition value. Because this condition value K_{ref} is produced when the corresponding machine part is new or newly renovated, possible later condition changes can be advantageously determined by comparison with the reference K_{ref}.

When the apparatus 30 is used to produce the reference condition value K_{ref}, a keyboard is connected to the information port 66 and the microprocessor is instructed to perform a reference-producing routine. The reference-producing routine involves the microcomputer 30 acquiring a measuring value from the sensor unit 20 and the display unit 62 showing a request for the operator to input the interpretation information which applies for the measuring point.

The interpretation information can be inputted, for example, via the keyboard or by means of a diskette which is introduced into the diskette station 64.

The microcomputer calculates the actual condition value K_{ref} indicating the condition of the individual measuring point depending on the measured value and the inputted interpretation information.

Both the condition reference value K_{ref} and the inputted interpretation information determined in this way are delivered to the information carrier 120 via the interface 70.

Alternatively, the interpretation data as well as the reference value K_{ref} can be delivered to the diskette unit 64 or the display unit/screen 62 in order to be inputted to the information carrier 120 in another way.

According to a preferred embodiment of the invention the device 80 comprises a readable and writable memory 120 which can exchange information in both directions with the interface 130. According to one embodiment the device 80 comprises a photoelectric cell which provides the power supply to the memory 120 and the interface 130.

Because the device 80 in the above described way is applied with a condition reference value which is individual for the machine and for the measuring point, later condition measuring can give advantageously accurate indications about changes in the condition. This means that the analysis apparatus does not have to be provided with any information at all about the machine or its measuring point, and despite this it is still possible to achieve an accurate evaluation of whether any changes in the condition have occurred. This is of considerable advantage, for example, during the checking of the condition of machines fixed to the floor in a large manufacturing industry, where the number of machines and measuring points is very large. It further provides a very good security as the risk of mixing of the data in a data base is eliminated by the reference condition value being stored directly at the measuring point.

A method for determining a possible change in the condition is usually performed with a certain regularity by maintenance personnel. A first example of when such a process can be performed, according to the invention, is when a machine has just been installed after delivery. In this situation there is already a condition reference value in the information carrier which has been generated and stored there in connection with the final inspection at the manufacturer of the machine.

When the installator has just installed the machine, the process is performed for determining a possible change in the condition with the purpose of verifying that the installation is correct and that the condition of the machine has not deteriorated during the transport from the manufacturer.

The method comprises the steps of:

- producing a measured value which depends on a movement of the machine;
- acquiring interpretation information from an information carrier which is mounted by the measuring point;
- producing an actual condition value, indicating the actual condition of the measuring point on the machine, dependent on the measured value and the interpretation;
- acquiring a second condition value, indicating the condition of the measuring point at an earlier point of time, from the information carrier;
- producing a relation value dependent on the actual condition value and the second condition value, which relation value indicates a change in the condition.

This process can be performed by the microprocessor 50 by it running an analysis routine which is stored in the memory 40.

The analysis routine comprises the step of the microprocessor 50 requesting measured values from the sensor unit 20. According to one embodiment of the invention the sensor unit comprises an accelerometer 140 with a piezo-electric element. When the measuring point 90 vibrates, the sensor unit 20, or at least a part of it, also vibrates and the accelerometer 140 then produces an electrical signal of which the frequency and amplitude depend on the mechanical vibration frequency and the vibration amplitude of the measuring point 90, respectively. The electrical signal is delivered to the analog-digital converter 34 which with a certain sampling frequency f_s converts the analog signal to consecutive digital words in a known way. The microcomputer 50 stores a series of digital words which correspond to a time sequence of the electrical signal in the memory 60, and then performs an analysis of the signal sequence, whereby the frequency and amplitude of the signal is determined. Consequently, a measured value for the vibration amplitude A_v and the vibration frequency f_v is determined. The microcomputer then takes the inter-

pretation information and the reference value K_{ref} from the device 80 by reading information from the interface 70.

According to one embodiment, the interface 130 on the device 80 comprises an opto-transmitter which transfers data serially to the interface 70 in the form of trains of pulses of infrared light.

The device 80 can be activated depending on an information request which is received via the interface 130. Alternatively, the device 80 comprises a detector element which senses if the sensor unit 20 is applied to the measuring point 90 and then activates the device 80 to send information to the interface 130.

In this way the microcomputer receives information on the identity of the measuring point and interpretation information, such as the diameter value d_1 and the rotational speed value V_1.

With knowledge of the interpretation information d_1 resp. V_1, each measured vibration amplitude value A_v can be easily converted to an actual condition value K_a. A predetermined interpretation algorithm is stored in the memory 40 and starting from an amplitude value A_v and interpretation information, such as d_1 and V_1, the microcomputer produces a corresponding condition value K_a dependent thereon. Such an interpretation algorithm is based on an embodiment of a method for producing a condition value described in the Swedish Laid-Open Document 339 576.

According to one embodiment, the interpretation algorithm is based on the machine classification standard ISO 2954.

The actual condition value K_a produced and the reference condition value K_{ref} acquired from the information carrier 120 are delivered to the screen 62 so that the

operator can judge if the two values correspond. If K_a is essentially similar to K_{ref}, the condition is essentially unchanged. If there is a discrepancy between the two values, then this indicates that the condition of the machine has changed.

Because the actual condition value K_a according to the invention can be compared with an earlier measured condition value K_{ref} for the same measuring point, an extremely accurate indication of changes is achieved. In this way, advantageously well-judged decisions can be made on when maintenance is required, which in turn leads to that the life length of the machine can be increased.

According to a preferred embodiment, the microcomputer produces a relation value in dependence of the actual condition value K_a and the reference condition value K_{ref}.

By dividing the value K_a with the reference K_{ref}, a relation value is achieved which gives a percentage change of the condition of the machine part or parts to which the measuring points relate. According to another embodiment the relation value is produced as the difference between the value K_a and the reference K_{ref}.

Claims

1. Method for the evaluation of the condition of a machine (100) with a measuring point (90), which method is performed by a movable analysis apparatus (30), comprising the steps of:

- producing a condition value by means of measuring at the measuring point, said condition value being dependent on the actual condition of the machine;

characterized by storing the condition value in a writable information carrier (120) which is placed by, or in the vicinity of, the measuring point (90) so that the condition value subsequently can be used as a reference condition value.

2. Method according to Claim 1, **characterized** by

- producing a measured value;
- acquiring interpretation information (d_1, V_1);
- generating the condition value dependent on the measured value (A_v) and the acquired interpretation information (d_1, V_1).

3. Method according to Claim 1 or 2, **characterized** in that the measured value indicates a movement, such as a vibration movement, of the machine.

4. Method according to any of the previous claims, **characterized** in that the interpretation information (d_1, V_1) corresponds to the technical type values for the machine or a part of the machine.

5. Method for evaluation of the condition of a machine (100) with a measuring point (90), comprising the steps of:

a) producing a condition value, said value being dependent on the actual condition at the measuring point,

characterized by

b) acquiring a reference value, indicating the condition of the machine at an earlier point of time, from an information carrier (120) which is placed by, or in the vicinity of, the measuring point (90).

6. Method according to Claim 5, comprising the step of:

c) producing a relation value dependent on the actual condition value and the reference value.

7. Method according to Claim 5 or 6, **characterized** in that step a) comprises the steps of:

a1) producing a measuring value by means of a measuring at the measuring point;

a2) acquiring interpretation information from the information carrier (120);

a3) generating the actual condition value (K) dependent on the measured value (A_v) and the interpretation information (d_1, V_1).

8. Method according to Claim 5 or 6, **characterized** in that the condition value is produced directly be means of measuring at the measuring point.

9. Method according to any of the previous claims, **characterized** in that

- the communication between the analysis apparatus and the information carrier is performed by means of radio communication or by means of optical transmitters and optical receivers.

10. Analysis apparatus for evaluation of the condition of a machine (100) with a measuring point (90), which apparatus comprises:

- a sensor means (20) for producing a measured value (A_v) dependent on a movement of the machine;
- a communication means (70;66;64) for receiving interpretation information specific to the measuring point;

- an information processing means (50,40,60) for producing a condition value, whereby the information processing means (50,40,60) co-operates with the communication means (70;66;64) and the sensor means (20) so that the information processing means produces a condition value ($K;K_{ref}$), dependent on the measured value and the interpretation information, indicating the actual condition of the machine, **characterized** in that the communication means comprises an interface means (70) which is arranged to transmit the condition value (K_{ref}) to a writable information carrier (120) by, or in the vicinity of, the measuring point (90) so that it can be used as a locally stored individual condition reference value.

11. Analysis apparatus for evaluation of the condition of a machine (100) with a measuring point (90), which apparatus comprises:

- a sensor means (20) for producing a measured value (A_v) dependent on a movement of the machine;
- a communication means (70;66;64) for receiving interpretation information specific to the measuring point;
- an information processing means (50,40,60) for producing a condition value, whereby the information processing means (50,40,60) co-operates with the communication means (70;66;64) and the sensor means (20) so that the information processing means dependent on the measured value and the interpretation information produces a condition value ($K;K_{ref}$) indicating the actual condition of the machine: **characterized** in that
- the communication means comprises an interface means (70) which is arranged to acquire a condition reference value indicating the condition of the machine at the measuring point at an earlier point of time, from an information carrier (120) placed by, or in the vicinity of, the measuring point (90).

12. Analysis apparatus according to Claim 10 or 11, **characterized** in that

- the interface means (70) is capable of both receiving and transmitting information.

13. Analysis apparatus according to Claim 10, 11 or 12, characterized in that

- the sensor means (20) is movably connected to the information processing means.

14. Analysis apparatus according to Claim 13, characterized in that

- the interface means (70) and the sensor means (20) are integrated in a common casing.

15. Analysis apparatus according to Claim 12, 13 or 14 when dependent on Claim 11, characterized in that

- the information processing means (50,40,60) by means of the communication means (70) is arranged to acquire the reference condition value, indicating the condition of the measuring point at an earlier point of time, from the information carrier; and that
- the information processing means (50,40,60) is arranged to produce a relation value dependent on the actual condition value and the reference condition value, which relation value indicates a changing condition.

16. Analysis apparatus according to any of Claims 10-15, characterized in that the analysis apparatus is arranged to generate the condition value in accordance with a predetermined algorithm.

17. Analysis apparatus according to any of Claims 10-16, characterized in that the analysis apparatus is a portable unit.

18. Analysis apparatus according to any of Claims 10-17, characterized in that

- the interface means (70) is adapted to communicate with the information carrier by means of radio communication or by means of optical senders and optical receivers.

19. Device for co-operating with an analysis apparatus according to any of Claims 10-18, and for mounting at a measuring point on a machine (100) with a movable part (110), which device comprises:

- a communication carrier (120);
- interpretation information, stored on the information carrier, which defines technical type values for the machine and/or the movable part in such a way that an actual condition value is able to be generated depending on an actual measured value when the measured value is interpreted in combination with the interpretation information;
- a communication means (130) for co-operating with the analysis apparatus, which, dependent on an activating signal, reads interpretation information from the information carrier and delivers this information to the analysis apparatus; whereby
- the information carrier is provided with a reference condition value indicating the condition of the measuring point at an earlier point of time; and
- the communication means, dependent on the activation signal, reads the reference condition value from the information carrier and delivers this to the analysis apparatus thereby enabling the generation of a relation value indicating a changed condition.

20. Device for co-operating with an analysis apparatus according to any of Claims 10-18, and for mounting at a measuring point on a machine (100) with a movable part (110), which device comprises:

- an information carrier (120);
- interpretation information, stored on the information carrier, which defines technical type values for the machine and/or the movable part in such a way that the actual condition value is able to be generated dependent on an actual measured value when the measured value is interpreted in combination with the interpretation information;

characterized in that the information carrier comprises a writable memory means so that storing of a local reference condition value is made possible.

21. Device according to Claim 20, **characterized** by

- the communication means (130) for co-operating with the information carrier (120) and for communicating with the analysis apparatus (30).

22. Device according to Claim 19 or 21, **characterized** in that

- the communication means (130) comprises a transceiver for communicating with the analysis apparatus (30) by means of radio communication or optical transmitters and optical receivers.

23. Device according to Claim 19 or 21, **characterized** in that

- the communication means (130) comprises contact means for ohmic contact between the information carrier (130) and the analysis apparatus (30;70).

24. Device according to any of Claims 19-23, **characterized** in that

- the information carrier is adapted to be rigidly mounted on a machine.

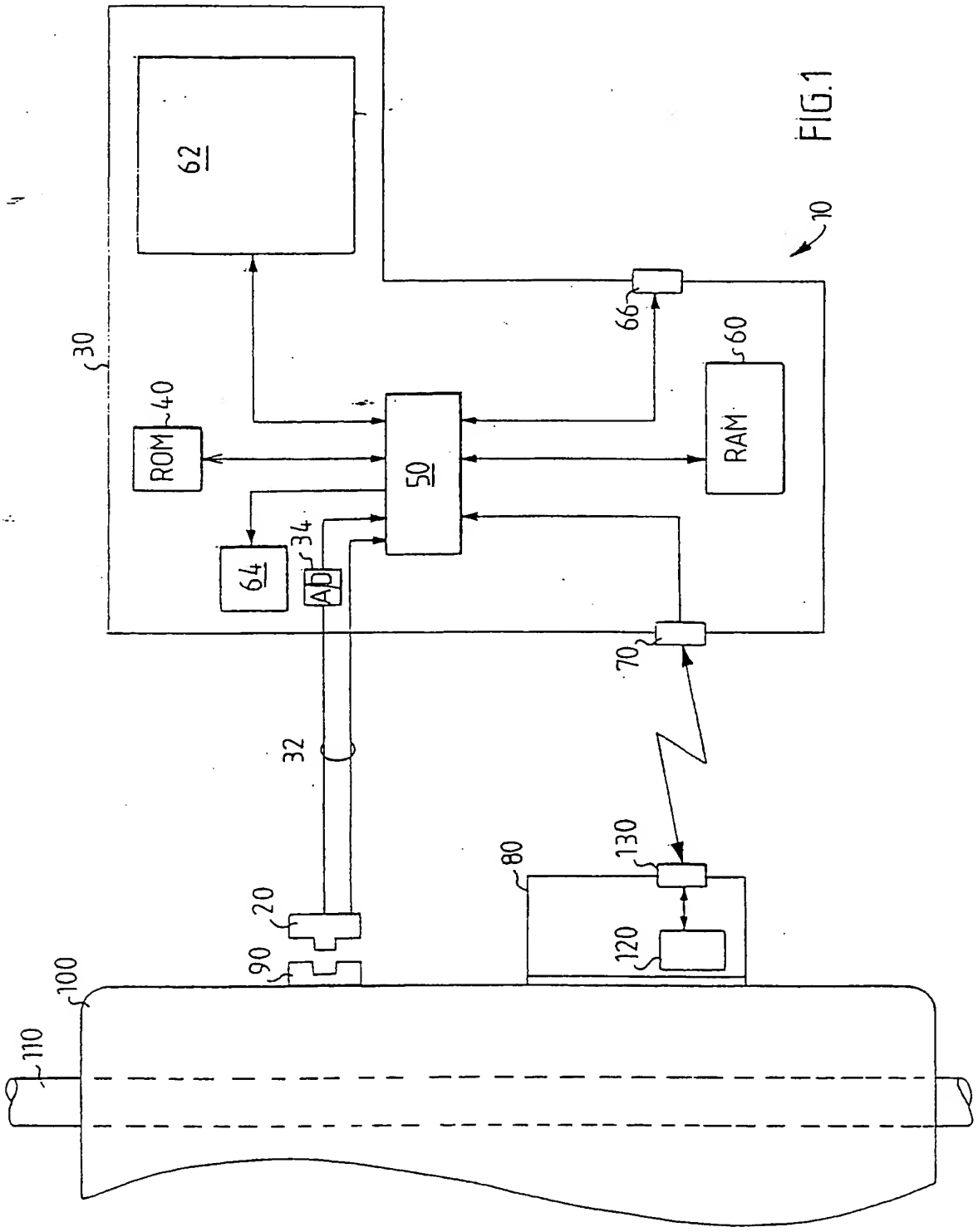

FIG.1

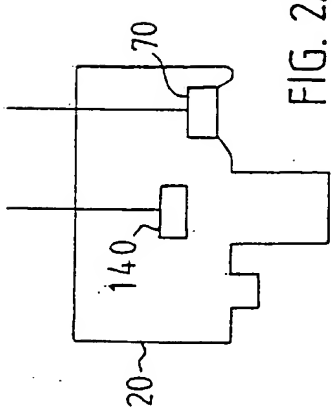

FIG. 2A

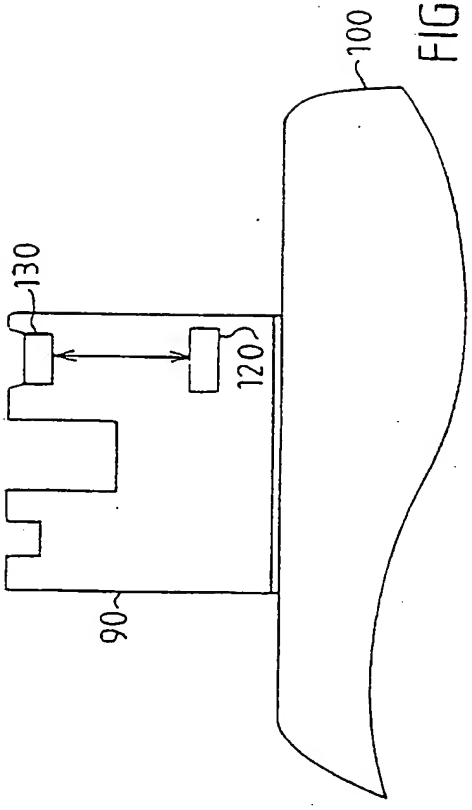

FIG. 2B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/01221

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G07C 3/00, G01M 13/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G07C, G01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5319962 A (D.KAMINSKI ET AL), 14 June 1994 (14.06.94), see the whole document	1-4,5-9
X	DE 4427880 A1 (STADELMANN,KURT), 15 February 1996 (15.02.96), see the whole document	1-4,5-9
A	US 4800512 A (D.BUSCH), 24 January 1989 (24.01.89), see the whole document	1-24
A	EP 0194333 A1 (SEE THE WHOLE DOCUMENT), 17 Sept 1989 (17.09.89), see the whole document	1-24

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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